Question 1: Screw Conveyor - refer Fig. 1

(a) A rotary screw conveyor is to be designed to elevate dry sand from the truck un-loader pit as illustrated in Fig 1, at a rate of 20 tonnes per hour, into the chute of the bucket elevator. The conveyor is a 6 m long inclined screw conveyor which elevates the material 2 m. It has a standard pitch screw and is to be selected from one of the standard diameters given in the tables.

Determine:

(i) The required screw diameter (mm),
(ii) The required screw speed (rpm),
(iii) The power required at the drive shaft (kW),
(iv) What special problems (list at least three) should be anticipated with this system? How should the special problems be combated?

Solution: using CEMA procedure:

<table>
<thead>
<tr>
<th>Dry sand:</th>
<th>Sand Dry Bank (Dry)</th>
<th>100B37</th>
<th>15</th>
<th>3D</th>
<th>90-110</th>
<th>1.7</th>
<th>15</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q</td>
<td>20 tonnes/hr</td>
<td>20,000</td>
<td>2.205</td>
<td>44,100 lb/hr</td>
<td>44,100/100</td>
<td>441 ft³/hr</td>
<td></td>
</tr>
<tr>
<td>( \sin \theta )</td>
<td>2/6</td>
<td>19.47 &amp; 200</td>
<td>(recommended max. = 16° - 18°)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>De-rate by about 20 %, hence assume Q = 441 X 100/80 = 551 ft³/hr</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(i) Table 1.6, 16 inch dia, screw carries 700 ft³/hr at 45 rpm

(ii) Use \( N = (551/700) \times 45 = 36 \text{ rpm} \)

\( HP_f = \frac{L N F_d F_b}{1,000,000} \)

\( HP_m = \frac{C L W F_f F_m F_p}{1,000,000} \)

Total HP = \( HP_f + HP_m \)

The following factors determine the horsepower requirement of a screw conveyor operating under the foregoing conditions.

| L = Total length of conveyor, feet | 6 x 3.281 | 19.7 ft |
| N = Operating speed, RPM (revolutions per minute) | 36 rpm |
| Fd = Conveyor diameter factor (See Table 1-12) | 106 |
| Fb = Hanger bearing factor (See Table 1-13) | 2 |
| C = Capacity in cubic feet per hour | 441 ft³/hr |
| W = Weight of material, lbs. per cubic foot | 100 |
| Ff = Flight factor (See Table 1-14) | 1 |
| Fm = Material factor (See Table 1-2) | 1.7 |
| Fp = Paddle factor, when required. (See Table 1-15) | 1 |
| Fo = Overload factor (See Table 1-16) | |
| \( e = \) Drive efficiency (See Table 1-17) | 0.87 |

*Non lubricated bearings, or bearings not additionally lubricated.

\( HP_f = \frac{L N F_d F_b}{1,000,000} = \frac{19.7 \times 36 \times 106 \times 2}{1,000,000} = 0.15 \)

\( HP_m = \frac{C L W F_f F_m F_p}{1,000,000} = \frac{441 \times 19.7 \times 100 \times 1 \times 1.7 \times 1}{1,000,000} = 1.48 \)

Total HP = \( 0.15 + 1.48 = 1.63 \) \( \times 1.7 = 2.87 \) \( \text{kW} \)

Total Power to convey the material horizontally = \( 3.18 \times 0.746 \) = 2.37 kW

Elevating power = \( \delta g H = (20/3.6) \times 9.81 \times 2 \) = 0.109 kW

(iii) Total power = 2.37 + 0.109 = 2.48 kW
Estimate the motor power required to drive the system.

Solution: using CEMA procedure:

<table>
<thead>
<tr>
<th>Material</th>
<th>lb/ft³</th>
<th>Abrasiveness</th>
<th>Corrosiveness</th>
<th>Flow-ability</th>
<th>recommended elevator</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potash (muriate of potash)</td>
<td>77</td>
<td>H</td>
<td>H</td>
<td>M</td>
<td>700</td>
</tr>
</tbody>
</table>

\[
Q = 20 \text{ tonnes/hr} = 20,000 \times 2.205 = 44,100 \text{ lb/hr} = 44,100/77 = 573 \text{ ft}^3/\text{hr}
\]

Lump size: small, < ¼ inch
Percentage of lumps: as above
Shaft centres: 15 X 3.281 = 49.2 feet
Service: 8 hours per day

Referring to Table 1, note that the material is highly abrasive, highly corrosive, relatively free flowing (angle of repose 30 to 45 degrees). Type 700 is recommended. The type 700 continuous elevator is selected as that best suited to handle the material. Referring to the capacity table for Type 700 elevators, it is found that a No. 703/4 elevator(s) will just handle the capacity and lump size of the material to be handled. Choose the larger elevator no 705.

Horsepower is then calculated as follows:

\[
\text{SHP} = (0.155 + 0.055 \times 49.2) \times 77/75 = 2.861 \times 77/75
\]

\[
\text{SHP} = 2.937
\]

Assuming a drive efficiency of 85 %, actual required power is then calculated as follows:

\[
P = 2.937/0.85 = 3.456 \text{ hp} = 3.4546 \times 0.746 = 2.578 \text{ kW}
\]

Theoretical Power = \(mgH = (20/3.6) \times 9.81 \times 15 = 0.818 \text{ kW}\)

Efficiency = (0.818/2.578) x 100 = 31.7 %

**Question 2: Pneumatic Handling**

Cement is to be conveyed pneumatically in a positive-pressure dilute-phase system according to the following specification.

- Particle/bulk properties: Refer to tables and make approximations where necessary
- Conveying rate, \(m_k\): refer Fig. 1
- Total length of conveying pipeline, \(L = 50 \text{ m}\).
- Internal diameter of conveying pipeline, \(D = 102 \text{ mm}\).
- Total pipeline air pressure drop, \(\Delta p_t = 50 \text{ kPa}\).
- Type of feeder: drop-through rotary valve (maximum rotor speed = 40 rpm).
- Air pressure inside feed bin on top of rotary valve feeder = 0 kPa g.
- Air pressure inside receiving bin at end of pipeline, \(p_{fe} = 5 \text{ kPa g}\).
- Mass flow rate of air flowing through pipeline \(m_f = 0.30 \text{ kg s}^{-1}\).
- Conveying air temperature, \(t = 50 \text{ °C}\).
- Atmospheric air pressure, \(P_{atm} = 101 \text{ kPa abs}\).
- Atmospheric air temperature, \(t_{atm} = 20 \text{ °C}\).
- Gas constant for air, \(R = 287.1 \text{ N m kg}^{-1} \text{K}^{-1}\).

(a) By using the continuity equation and the ideal gas law, determine the superficial air velocity at the feed point \(V_{f1}\) and at the end of the pipeline \(V_{fe}\).

(b) For a maximum rotor speed of 40 rpm and using Eq (6) of the Lecture Notes “Design Requirements for Rotary Valves”, determine the minimum swept volume \(\Psi\) of rotary valve for this application (ie to ensure that a conveying rate of at least 16 t h\(^{-1}\) is achieved).

(c) Based on available sizes of rotary valve with 8 rotor pockets (viz \(\Psi = 6, 13, 22 \text{ and 36 litres/rev}\)), select the smallest rotary valve size for this application. Also, for this valve, determine a suitable rotor speed to achieve the desired conveying rate. Hint: determine the required value of \(\alpha N\) and then by considering various values of \(N\), use iteration with minimum values of filling factor \(\alpha\).
### Solution:

**Mass flow**, \( \dot{m} = 16 \text{ tonnes/hr} = 16/3.6 = 4.44 \text{ kg/s} 

(a) 

\[
\rho_p = \frac{P}{RT} = \frac{(101+55)\times10^4}{287.1\times323} = 1.682 \text{ kg/m}^3
\]

\[
\rho_f = \frac{P}{RT} = \frac{(101+5)\times10^4}{287.1\times323} = 1.143 \text{ kg/m}^3
\]

\[
\eta = \frac{\dot{m}_s}{\dot{m}_f} = \frac{4.44}{0.30} = 14.8
\]

\[
V_p = \frac{\dot{m}_s}{\rho_p A} = \frac{0.3}{1.682 \times (\pi/4) \times 0.102^2} = 21.83 \text{ m/s}
\]

\[
V_f = \frac{\dot{m}_f}{\rho_f A} = \frac{0.3}{1.143 \times (\pi/4) \times 0.102^2} = 32.12 \text{ m/s}
\]

(b) 

\( \rho_{\text{bulk}} \) for cement = 1240 kg/m\(^3\), 95% size < 0.090 mm Assume \( d_{50} = 0.050 \text{ mm} \)

\( \rho_s \) = 2800 kg/m\(^3\)?

Figure 14 from notes give \( \alpha = 0.55 \) for \( N = 40 \text{ rpm} \) and \( d_{50} = 0.050 \text{ mm} \)

\[
\dot{m}_s = \alpha \rho_{\text{bulk}} \psi N, \quad \psi = \frac{\dot{m}_s}{\alpha \rho_{\text{bulk}} N} = \frac{\left(12,000/60\right)}{0.55 \times 1240 \times 40} = 0.00733 \text{ m}^3/\text{rev} = 7.33 \text{ l/rev}
\]

**OR**

\[
\psi = \frac{\dot{m}_s}{\alpha \rho_{\text{bulk}} N} = \frac{(16,000/60)}{0.55 \times 1240 \times 40} = 0.00978 \text{ m}^3/\text{rev} = 9.78 \text{ l/rev}
\]

(c) 

\[
\psi = \frac{\dot{m}_s}{\rho_{\text{bulk}} \alpha N} = \frac{12,000}{1240 \alpha N} = 0.1613 \frac{\alpha N}{\alpha N} \quad \text{OR} \quad \psi = \frac{\dot{m}_s}{\rho_{\text{bulk}} \alpha N} = \frac{16,000/60}{1240 \alpha N} = 0.215 \frac{\alpha N}{\alpha N}
\]

<table>
<thead>
<tr>
<th>( N )</th>
<th>( \alpha )</th>
<th>( \psi )</th>
<th>( N )</th>
<th>( \alpha )</th>
<th>( \psi )</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>0.95</td>
<td>30.0</td>
<td>5</td>
<td>0.95</td>
<td>50.6</td>
</tr>
<tr>
<td>10</td>
<td>0.8</td>
<td>20.2</td>
<td>10</td>
<td>0.8</td>
<td>26.9</td>
</tr>
<tr>
<td>15</td>
<td>0.75</td>
<td>14.3</td>
<td>15</td>
<td>0.75</td>
<td>19.1</td>
</tr>
<tr>
<td>20</td>
<td>0.72</td>
<td>11.2</td>
<td>20</td>
<td>0.72</td>
<td>14.9</td>
</tr>
<tr>
<td>25</td>
<td>0.68</td>
<td>9.5</td>
<td>25</td>
<td>0.68</td>
<td>12.6</td>
</tr>
<tr>
<td>30</td>
<td>0.64</td>
<td>8.4</td>
<td>30</td>
<td>0.64</td>
<td>11.2</td>
</tr>
<tr>
<td>35</td>
<td>0.6</td>
<td>7.7</td>
<td>35</td>
<td>0.6</td>
<td>10.2</td>
</tr>
<tr>
<td>40</td>
<td>0.55</td>
<td>7.3</td>
<td>40</td>
<td>0.55</td>
<td>9.6</td>
</tr>
</tbody>
</table>

Use about 19 RPM  Use about 25 RPM
Question 3:  Sampling and Weighing

(a)  (i) Describe how the horizontal force component is eliminated in a belt weigh feeder. Illustrate two 
    methods.  (2 marks)

(ii) With the aid of sketches (or reference to sketches) discuss the potential sources of error in measuring 
    with weigh-feeders.  (2 marks)

(iii) How may the weight of the weigh frame, belt and weigh idlers be compensated?  (2 mark)

(iv) Discuss the problems of material segregation in two practical situations.  (2 mark)

(b) A variable gate weigh feeder (Figure 3) is being commissioned to control feed rate of cement clinker to a 
    process. Records are as indicated below.

![Figure 3: Variable gate weigh feeder](image)

The idler spacing is even over the weighing region and the effective belt width is 900 mm. If the feed rate is intended to 
be 450 tonnes per hour, determine the following actual parameters:  (2 marks ea)

(i) The average height of material on the belt (mm) during the period recorded.

(ii) Average volume feed rate. (m$^3$/s).

(iii) Mass feed rate. (kg/s and tonne / hr).

(iv) Is the feed rate satisfactory? If not, what could be done to correct to situation? Discuss the options.

Solution to 3 (b)  see notes for answers to 3 (a):

<table>
<thead>
<tr>
<th>Indicated load (net) (kg)</th>
<th>136</th>
<th>140</th>
<th>142</th>
<th>137</th>
<th>122</th>
<th>155</th>
<th>144</th>
<th>129</th>
</tr>
</thead>
<tbody>
<tr>
<td>Belt speed (m/s)</td>
<td>2.0</td>
<td>2.1</td>
<td>1.95</td>
<td>2.15</td>
<td>1.85</td>
<td>1.8</td>
<td>2.0</td>
<td>1.85</td>
</tr>
<tr>
<td>($W$) x ($v$)</td>
<td>272</td>
<td>294</td>
<td>276.9</td>
<td>294.55</td>
<td>225.7</td>
<td>279</td>
<td>288</td>
<td>238.65</td>
</tr>
</tbody>
</table>

The indicated load is 138.125 kg, the belt speed is 1.963 m/s, and the effective belt width is 900 mm. If the feed rate is intended to 
be 450 tonnes per hour, determine the following actual parameters:

(i) The average height of material on the belt (mm) during the period recorded.

(ii) Average volume feed rate. (m$^3$/s).

(iii) Mass feed rate. (kg/s and tonne / hr).

(iv) Is the feed rate satisfactory? If not, what could be done to correct to situation? Discuss the options.

Solution to 3 (b)  see notes for answers to 3 (a):

<table>
<thead>
<tr>
<th>Indicated load (net), W, (kg)</th>
<th>136</th>
<th>140</th>
<th>142</th>
<th>137</th>
<th>122</th>
<th>155</th>
<th>144</th>
<th>129</th>
</tr>
</thead>
<tbody>
<tr>
<td>Belt speed, $v$, (m/s)</td>
<td>2.0</td>
<td>2.1</td>
<td>1.95</td>
<td>2.15</td>
<td>1.85</td>
<td>1.8</td>
<td>2.0</td>
<td>1.85</td>
</tr>
<tr>
<td>($W$) x ($v$)</td>
<td>272</td>
<td>294</td>
<td>276.9</td>
<td>294.55</td>
<td>225.7</td>
<td>279</td>
<td>288</td>
<td>238.65</td>
</tr>
</tbody>
</table>

$W = \rho_{\text{bulk}} (Lbh) = 1360(2.5 \times 0.9h) = 3,060 \text{ kg}$

(i) 138.13 = 3,060 h, $h = 0.0451 \text{ m} = 45.1 \text{ mm}$

(ii) $Q = vA = 1.963 \times 0.9 \times 0.0451 = 0.0797 \text{ m}^3/\text{s}$

(iii) $m = \rho_{\text{bulk}} Q = 1.360 \times 0.0797 = 108.4 \text{ kg/sec} = 108.4 \times 3.6 = 390.2 \text{ tonnes/hr}$
Question 4: Belt Conveyor

Using the Dunlop procedure to carry coal at 1000 tonnes/hour:
Select a belt width based on a reasonable belt velocity, trough angle of 30° and surcharge angle of 20° based on the material which is coal of size < 3 mm and bulk density 0.96 tonne/m³.

Other data:
- Length of belt = 650 m
- Height of lift = 150 m.
- Speed of belt = {? m/min.}
- Head pulley diameter = 915 mm lagged.
- Angle of wrap at head (drive) pulley = 310°.

(a) Determine the total power requirement at the head shaft.
(b) Select a suitable motor power for the job and calculate the belt tensions (assuming full motor power is being used at the head shaft).
(c) Select a suitable friction coefficient between head pulley and belt.
(d) Initial tension is acquired by the use of a counterweight. Determine a weight necessary to provide the tension for the tensioning arrangement below. Describe the factors influencing belt stretch and hence H in Fig 4
(e) List any special problems that the material may present and suggest suitable corrective measures.

Solution (Dunlop steps 1.] to 12.]

1.] \( Q = 0.278 \frac{T}{S} = 0.278 \times 1000/3 = 92.67 \text{ kg/m} \)

2.] Table 10: (try belt width of 1050 mm and speed 3 m/s after looking at Table 3) assume medium duty, then mass of moving parts is \( G = 64 \text{ kg/m} \)

3.] \( L_c = L + 70 = 650 + 70 = 720. \ C = \frac{L_c}{L} = \frac{720}{650} = 1.108 \)

4.] Tension empty: \( T_x = 9.8 \times G \times f_x \times L_c = 9.8 \times 64 \times 0.020 \times 720 = 9,031 \text{ N} \)

5.] Tension load: \( T_y = 9.8 \times Q \times f_y \times L_c = 9.8 \times 92.67 \times 0.022 \times 720 = 14,385 \text{ N} \)

6.] Tension to lift: \( T_z = 9.8 \times Q \times H = 9.8 \times 92.67 \times 150 = 136,225 \text{ N} \)

7.] Accessories \( T_u = 0 \)

8.] Effective tension: \( T_e = 9,031 + 14,385 + 136,225 = 159,641 \text{ N} \)

9.] Absorbed power: \( P = \frac{T_e \times S}{159,641 \times 3} = \frac{478.9 \text{ kW}}{159,641} \)

10.] \( \mu = 0.35 \text{ for lagged pulley}. \ \theta = 310^\circ = 310 \times \frac{\pi}{180} = 5.41 \text{ rad} \)

\[ e^{\mu \theta} = e^{0.35 \times 5.41} = 6.642577. \]

\[ k = \frac{1}{e^{\mu \theta} - 1} = 1/5.643 = 0.177 \]

\[ T_m = k \times T_e = 0.177 \times 159,641 = 28,256 \text{ N} \]

\[ T_s = 9.8 \times S_f \times (B + Q) \times (\text{Id} \text{ assume Id} = 0.9) = 9.8 \times 6.3(13 + 92.7) \times 0.9 = 5,873 \text{ N} \]

\[ T_m >> T_s, \text{ use } T_2 = 28,256 \text{ N} \]

11.] \( T_h = 9.8 \times B \times H = 9.8 \times 13 \times 150 = 19,110 \text{ N} \)

12.] \( T_1 = T_e + T_2 + T_h = 159,641 + 28,256 + 19,110 = 207,007 \text{ N} \)

\[ \text{Effective tension, } T = \frac{T_1}{w} = \frac{207,007/1050}{197} = \text{ Use class 1000 or St 800} \]

(a) Assuming 10% extra for starting use a \textbf{550 kW motor}

(b) See 10] – 12] above,

(c) \( \mu = 0.35 \text{ from old Dunlop tables} \)

(d) \( F_1 = 2 \times T_2 = 2 \times 28,256 = \textbf{56,512 N} \)

(e) Descriptive
**Question 5: Pumping of Slurries**

A centrifugal sand pump is required for the following duty:

100 tonnes per hour of a material having a particle distribution approximated by the graph (Figure 5) below.

- Specific gravity of solids, $S = 2.65$
- Concentration of solids, $C_w = 40\%$ by weight
- Static discharge head, $Z_d = 50$ metres
- Suction head, $Z_s = 2.5$ metres (+)
- Length of pipeline = 180 metres
- Valve and fittings = 5 X 90° LR bends, 2 X diaphragm valves

Determine the following:

(a) Specific gravity of slurry mixture, $S_m$
(b) Concentration by volume, $C_v$
(c) Volumetric flow of slurry.
(d) Pipeline size.
(e) Total dynamic head on the pump.

**Solution:**

Weight of solids in slurry $= 100$ tonnes
Weight of equal volume of water $= \frac{100}{2.65} = 37.74$ tonnes
Weight of water in slurry ($C_w = 40\%$) $= \frac{100(100 - 40)}{40} = 150$ tonnes
Total weight of equal volume of water $= 150 + 37.74 = 187.74$ tonnes
Total weight of slurry $= 100 + 150 = 250$ tonnes

(a) Specific gravity of slurry mixture $= \frac{250}{187.74}$ $SG = 1.33$

(b) Concentration by vol. $= \left(\frac{37.74}{187.74}\right) \times 100 = C_v = 20.1\%$

(c) $Q = \frac{187.74}{3.6} = 52.15$ l/s

(d) Check flow in dia. 150 pipe: 

\[
A = \frac{\pi}{4} \times 0.15^2 = 0.0177 m^2
\]

\[
v = \frac{Q}{A} = 52.15 \times 10^{-3} / 0.0177 = 2.95 m/s
\]

Durand’s equation:

\[
V_L = F_L \sqrt{\frac{2gD(S - S_f)}{S_f}}, \quad F_L = 1.05 \text{ from Warman graph}
\]

\[
V_L = 1.05 \sqrt{\frac{2 \times 9.81 \times 0.15 \times (2.65-1)}{1}} = 2.31 m/s
\]

$v$ sufficiently $> V_L$ so dia. 150 mm pipe-work is acceptable

(e) Length of pipe $= 180$ m
5 x 90 deg. LR bends $= 5 \times 3.35 = 16.75$ m
2 x diaphragm valves $= 2 \times 18.29 = 36.58$ m
Equivalent length of pipe-work $= 233.3$ m

Darcy Equation, $f = 0.017$ from Moody chart:

\[
H_f = f \frac{L \sqrt{v^2}}{D} \frac{\sqrt{2g}}{2g} = 0.017 \times \frac{233.3}{0.15} \times \frac{2.95^2}{2 \times 9.81} = 11.73$ m
\]

Other pipe-work losses:

Entry loss $= 0.5 \left(\frac{v^2}{2g}\right) = 0.5 \times (2.95^2/(2 \times 9.81)) = 0.22$ m
Exit loss $= \frac{v^2}{2g} = \frac{2.95^2}{(2 \times 9.81)} = 0.44$ m
Enlargement loss at pump to delivery pipe transition $= 0.3$ m

\[
H_m = z + H_f = 50 - 2.5 + 11.73 + 0.22 + 0.44 + 0.3 = 60.2$ m
\]
Answer:

6 (a) \( \mu = \) coefficient of friction between bulk material and side wall  
\( \gamma = \) bulk weight (N/m\(^3\))  
\( p = \) vertical pressure at depth \( x \) (N/m\(^2\))  
\( p_s = \) wall pressure (N/m\(^2\))  
\( s = \) length of side wall (m)

\[ \Sigma \uparrow F_x = 0 = s^2 \delta p - \gamma s^2 \delta x + 4 \mu p_s \delta x \]

But \( \mu p_s = k_p \), hence substitute in above equation

\[ s^2 \delta p - \gamma s^2 \delta x + 4 k p_s \delta x = 0 \]

Divide throughout by \( s^2 \)

\[ \delta p - \gamma \delta x + \frac{4 k p_s}{s} \delta x = 0 \]

\[ \delta p = \left( \gamma - \frac{4 k p_s}{s} \right) \delta x \]

\[ \frac{d p}{\left( \gamma - \frac{4 k p_s}{s} \right)} = \frac{4 k}{s} d x \]

Integrate both sides of above equation

\[ \ln \left[ \frac{s}{4 k} \gamma - p \right] = - \frac{4 k}{s} x + C \]

\[ \left( \frac{s}{4 k} \gamma - p \right) = Ke^{-\frac{4 k}{s} x} \]

Substitute boundary conditions: \( p = 0 \) when \( x = 0 \)

Then \( K = \left( \frac{s}{4 k} \gamma \right) \). Substitute this in the above equation

\[ p = \frac{\gamma s}{4 k} \left[ 1 - e^{-\frac{4 k}{s} x} \right] \]

Total downward force at \( x = P = ps^2 \)

\[ P = \frac{\gamma s^3}{4 k} \left[ 1 - e^{-\frac{4 k}{s} x} \right] \]
(b) Of the various parameters and material properties, most significant in friction characteristics at contact of bulk solid with wall.

**LOADING & ENVIRONMENTAL FACTORS**

**WALL SURFACE CHARACTERISTICS**

**WALL & FRICTION**

Wall friction depends on:
- Variables related to bulk solid
- Variables related to wall/boundary surface
- Variables dependent on loading/environment

Wall friction characteristics are displayed by wall yield locus (WYL) as:

$$\theta = \tan^{-1}\frac{\tau}{\sigma}$$

**To conveyors**

The friction characteristics play a vital role in the selection & design of conveyors. This is because friction is a major cause for wear and tear of mechanical parts and results in a large loss of energy.

Hence friction leads to a decrease in equipment efficiency & conveyor construction material.

(c) Wall or boundary friction can be measured using the Jenike direct shear apparatus as shown below.

![Shear Ring Diagram](image)

The normal load V is varied to obtain a locus of points for the values of shear force S for each normal load V. Curve obtained is called wall yield locus (WYL).

Adhesive/Cohesive properties are exhibited in this experiment.

The Jenike shear apparatus does not allow for measurement of adhesion directly.

(d) When a granular solid is charged into a bin.
Question 7: Bins and Feeders (approximately 2.5 marks ea, total 16 marks)

IN YOUR ANSWERS USE DIAGRAMS OR REFER TO DIAGRAMS IN NOTES

(a) Explain the importance of “mass flow” when feeding from a bin on to a belt feeder. Discuss three factors influencing mass flow.

(b) What are the problems caused by rat holes and arching in bins? Discuss in terms of material properties and bin geometry.

(c) Describe in terms of material properties and bin geometry how a wedge shaped hopper is useful?

(d) A screw feeder is used to supply 5 tonnes of sugar per hour from a bin to a food process plant. Select a suitable screw diameter(s) and its operating speed.

(e) For the screw feeder above, determine a suitable electric motor power rating assuming a suitable gear reducer of and a feeder length of 1.8 M.

(f) Suggest suitable feeders for the following materials:
   (i) Cashew nuts.
   (ii) Wet sewage.
   (v) Tree bark, < 30 mm.

Student attempts Answer for (a), (b), (c) and (f), descriptive:
Solution for (d) and (e):

Answer 7:
(a) Mass Flow.

(b) Ratholing and Arching.

In the diagram:
- Mass flow does not imply plug flow at equal velocity.
- Typically needs a rounded hopper to enhance mass flow.
- Importance of mass flow:
  - Flow is more consistent
  - Reduces effects of radial segregation
  - Stress field is more predictable
  - Full bin capacity is utilised
  - First in / First out

Factors influencing mass flow:
- Height of hopper
- Cone angle
- Shape of hopper
- Material properties like flowability
Pecking causes a traffic jam at the outlet of the bin due to too many large particles competing for small outlet.

Rattling allows a funnel type flow creating a 'dead' or 'no flow' region along the walls.

The above lead to a reduction in effective storage capacity. This essentially means adding a higher cone angle to changing geometry of shape to suit type of material.

(c) A wedge shaped hopper assists in material flow properties. This is because the hopper is in wedge shape and can be adjusted to a required height as required.

(d) \[ C = \frac{5 \text{ tonnes/hr}}{960 \text{ kg/m}^3} \]

\[ x = 0.3 \times \frac{0.1}{5.21} \]

\[ x = 3.04 \times 10^{-2} \text{ m/kg} \]

\[ \text{Take: } 17.4 \text{ ft}^3/\text{hr} \]

From table 8.2, pg 261 Screw diameter is 9 INCHES @ 65RPM

(e) \[ H^p_{\text{empty}} = \frac{6 \times 65 \times 27 \times 2}{10^6} \]

Assume soft bearings hence `2'

\[ H^p_{\text{empty}} = 0.021 \]

\[ H^p_{\text{material}} = \frac{6 \times 17.4 \times W \times 1}{10^6} \]

\[ H^p_{\text{feeder}} = H^p_{\text{empty}} + H^p_{\text{material}} \times 0.9 \]

(f) (i) Vibratory feeder
(ii) Belt
(iii) Screw / Auger
Question 8: Discrete Handling of Materials. See Q 10.9 (notes)

(a) Four forklift trucks are used to deliver pallet loads of parts between work cells in a factory. Calculate the maximum hourly delivery rate based on the data below.

Data:
- Average travel distances (loaded and empty) = 100 m
- Speed = 5 km/hr (loaded) and 7 km/hr (empty)
- Terminal time per average delivery = 1.0 min (0.5 min each of load and unload)
- Traffic factor = 0.9
- Availability = 1.0
- Work efficiency = 0.95

(b) Discuss the major trend in industrial materials handling. Refer to practical examples.

END OF PAPER

Solution for (a), (b) is descriptive:

\[ T_c = T_L + \frac{L_d}{v_c} + T_U + \frac{L_e}{v_c} \]

\[ T_c = 0.5 + \frac{100}{5000/60} + 0.5 + \frac{100}{7000/60} = 3.06 \text{ min} \]

\[ AT = 60 AT_f E \]

\[ AT = 60 \times 1 \times 0.9 \times 0.95 = 51.3 \text{ min/hr} \]

\[ WL = n_c \times AT = 4 \times 51.3 = 205.2 \text{ min/hr} \]

\[ R_f = \frac{WL}{T_c} = \frac{205.2}{3.06} = 67 \text{ deliveries per hr.} \]